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ABB

CONTROL ENGINEERING

# THE 4 BIGGEST MISTAKES

## IN INSTRUMENTATION AND HOW TO AVOID THEM

# THE FOUR BIGGEST MISTAKES IN INSTRUMENTATION ...

**Despite ongoing advancements in measurement and communications technology, instrumenting a process for feedback control remains a technical challenge. Today's sensors are certainly more sophisticated than ever before, and fieldbus technology has simplified many installation issues considerably. Nonetheless, much can still go wrong with an instrumentation project.**

**The problem lies in the straightforward nature of instrumentation projects: each variable to be measured must be matched with the most appropriate sensor; the sensor must be installed, calibrated, and interfaced to the controller; and the information generated by the sensor must be filtered, factored, and filed in order to give the controller an accurate picture of what's going on in the process. This apparent simplicity is what often leads to a false sense of security and missteps in a minefield of potential problems.**

**With that in mind, here are four circumstances you definitely want to avoid.**

## >>Mistake #1:

### Selecting the wrong sensor

#### Technology mismatch

Although it's generally obvious what quantity needs to be measured in a flow, temperature, or pressure control application, it's not always obvious what kind of flow meter, temperature sensor, or pressure gauge is best suited to the job. A mismatch between the sensing technology and the material to be sensed can lead to skewed measurements and severely degraded control.

This is especially true when measuring flow rates. All flow meters are designed to measure the rate at which a gas or liquid has been passing through a particular section of pipe, but not all flow meters can measure all flows. A magnetic flow meter or *magmeter*, for example, can only detect the flow of electrically conductive materials by means of magnetic induction. Non-conductive fluids like pure water will pass through a magmeter undetected.

Magmeters also have trouble distinguishing air bubbles from the fluid in the pipe. As a result, a magmeter will always yield an artificially high reading when bubbles pass through because it cannot sense the decrease in fluid volume caused by the presence of the bubbles. In a feedback loop, this occurrrence would cause the controller to throttle back the flow rate more than necessary, preventing the required volume of fluid from reaching the downstream process.

The problem gets even worse if the pipe is so full of air that it is only partially filled with liquid, a condition known as *open channel*. Although recent technological innovations allow certain magmeters to work in such a challenging environment, mechanical sensors such as turbines yield artificially high readings, since a trickle of fluid will move the meter's mechanism just as much as a full-pipe flow traveling at the same speed. On the other hand, mechanical sensors are not affected by the conductivity

of the fluid, so they will sometimes work where magmeters fail.

An even more challenging application is the measurement of pH in a caustic liquid such as the slurries found in paper mills. A general-purpose pH probe made of corrodible materials might not only generate inaccurate data, it might die altogether, sometimes within a matter of days. Some probes, such as those offered by ABB, are specifically designed for such tough environments. They can double, triple, and even quadruple probe life in many applications.

The trick is to find the right technology for the application, or to choose instruments that span a broader range of solutions. For example, new digital technologies allow some flow meters to solve many more flow problems than their predecessors.

Instrumentation vendors can be of help in avoiding the technology mismatch mistake. The best vendors train their sales people to assist with sensor selection and provide clients with easy-to-use selection guides. Some even offer extensive look-up tables based on product number, application, and serial numbers of past installations—an especially useful service when replacing older products.

Finding all the right parts can also be a challenge. Some instruments require specific housings, mounting hardware, and transmitters to forward the sensor's data to the controller. The right vendor can make all the difference by providing the entire assembly under a single catalog number. When it comes to temperature instrumentation, for example, training costs and purchasing effort are reduced when then vendor offers compatible probes and transmitters together as a package.

**Paying too much (or too little)**

Correct sensor selection is also a matter of balancing cost against performance. When there's a choice of equally effective technologies, the right choice is generally the cheapest one that gets the job done.

Temperature instrumentation is a classic example. The two dominant technologies are *resistance temperature detectors* (RTDs) and *thermocouples*. An RTD consists of a metal plate or rod through which a current is passed. The resistance that the current encounters varies with the temperature of the metal. A thermocouple consists of two dissimilar metal wires joined together at one end. The voltage between the unjoined ends varies with the temperature of the joint. Both yield voltages that can be electronically interpreted to indicate the temperature of the surroundings.

Thermocouples are generally cheaper, though less accurate than RTDs. If the application does not require particularly tight temperature control, an inexpensive thermocouple and a well-tuned PID loop should do the trick. But for processes that will only work correctly at very specific temperatures, it would be a mistake not to pay for the greater accuracy that an RTD affords. The cost of scrapping a batch of under-cooked or scorched products would eventually dwarf any savings in equipment costs.

A fast sensor can also be worth the extra cost. If the process requires a rapid succession of heating and cooling cycles, the temperature sensor must be able to generate a reading before it's too late to be of any use. Despite their cheaper pedigree, thermocouples tend to respond faster than RTDs—so if speed is the only important performance issue, choose a thermocouple.

## >> Mistake #2: Installing sensors incorrectly

**Placement**

The best sensor can yield disappointing results if not installed correctly. Magmeters, for example, tend to generate noisy signals if the flow they're measuring is turbulent. Bends, junctions, and valves in a pipe can all cause turbulence, thus magmeters work best when installed in sections of straight pipe.

Temperature sensors are also sensitive to placement. Even a highly accurate RTD tucked in the corner of a mixing chamber will only be able to detect the temperature of its immediate vicinity. If the mixing of the material in the chamber is incomplete, that local temperature may or may not represent the temperature of the material elsewhere in the chamber.

Local temperature issues are the classic mistake that home heating contractors often make when installing household thermostats. A

mounting location closest to the furnace may be convenient for wiring purposes, but if that spot happens to be in a hallway or other dead air space, the thermostat will not be able to determine the average temperature elsewhere in the house. It will only be able to maintain the desired temperature in its immediate vicinity. The rest of the house may end up roasting or freezing.

### Controller performance

Poor control also results when a sensor is installed too far away from the associated actuator. A distant sensor may not be able to measure the effects of the actuator's last move in time for the controller to make an educated decision about what to do next.

For example, consider the process of flattening hot steel into uniform sheets by means of two opposing rollers (see Figure 1). A thickness sensor downstream from the rollers gauges the sheet and causes the controller to apply either more or less pressure to compensate for any out-of-spec thickness.

Ideally, the thickness sensor should be located adjacent to the rollers to minimize the time between a change in roller pressure and the resulting change in the thickness measurement. Otherwise, the controller will not be able to detect any mistakes it may have been making soon enough to prevent even more of the sheet from turning out too thick or thin.

Worse still, an appreciable dead time between the controller's actions and the resulting effects on the steel can cause the controller to become impatient. It will see no results from an initial control move, so it will make another and another until some change begins to appear in the measurements reported by the sensor. By that time, the controller's cumulative efforts will have already overcompensated for the original error, causing an error in the opposite direction. The result will be a constant series of up and down swings in the roller pressure and a lot of steel ruined by lateral corrugations.

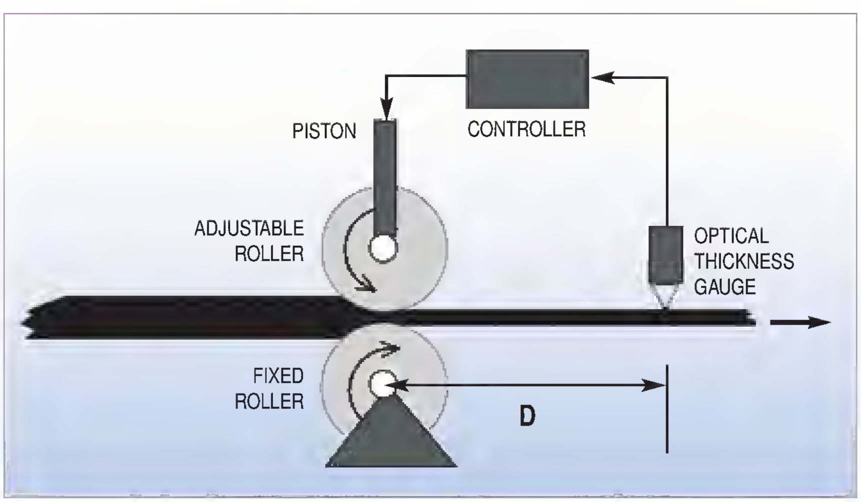
Of course, overall process performance considerations aren't limited to how well the sensor feeds data to the controller during operation. Other factors to consider include ease of installation and time spent on the selection process, set up routines, and any labor-intensive maintenance. Fortunately, some instrumentation vendors design their sensors to accommodate such challenges, thereby improving performance before the system even goes online. ABB, for instance, offers a swirl flowmeter that significantly reduces the need to install special upstream and downstream devices to accurately measure the flow through a pipe.

### Protection

A steel mill is also a classic example of a harsh environment that can destroy inadequately protected sensors. Fortunately, the hazards posed by a manufacturing process are generally obvious and can often be overcome by installing a shield or choosing a rugged instrument.

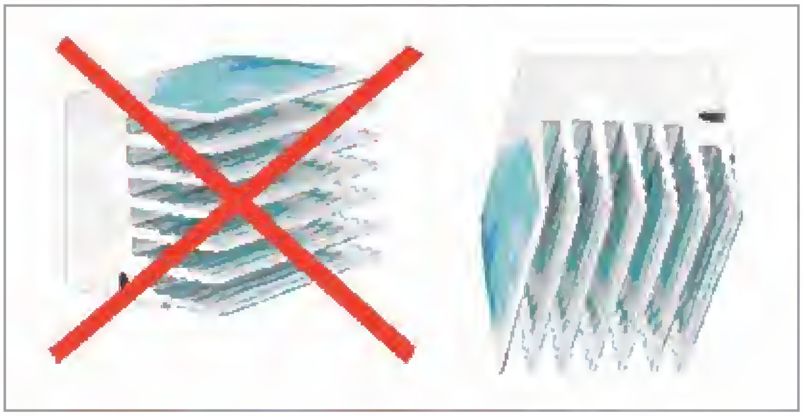
Often overlooked, however, are the effects of weather. Outdoor instruments can take quite a beating from rain, snow, hail, and falling

**FIGURE 1. POOR SENSOR PLACEMENT**




*In this steel rolling example, D is the distance between the steel rollers and the thickness gauge downstream. If D is too large, the controller will take too long to correct thickness errors and may even make matters worse by becoming impatient.*

**FIGURE 2. POOR MOUNTING**



*Even the orientation of an instrument can affect its performance. Here, the sensor is enclosed in a housing designed to dissipate the heat it generates. The fins must be mounted vertically to allow warm air to escape.*

ice. Over time, outdoor instruments can fail slowly unless enclosed in appropriate housings.

But even the housings themselves can cause problems for the enclosed instruments, particularly temperature sensors. If an RTD or thermocouple is mounted on the same piece of metal that supports the housing, the housing will work like a heat sink when the ambient temperature drops low enough. It will tend to draw heat out of the sensor and artificially lower its reading. The heat-sink effect will also tend to reduce the benefits of any internal heat that has been applied to prevent an instrument from freezing.

Conversely, if a housing is equipped with fins intended to draw heat out of the enclosed sensor during warm weather, the fins must be mounted vertically. Otherwise, the warm air around the fins will not be able to rise away from the housing (see Figure 2).

### Ground loops

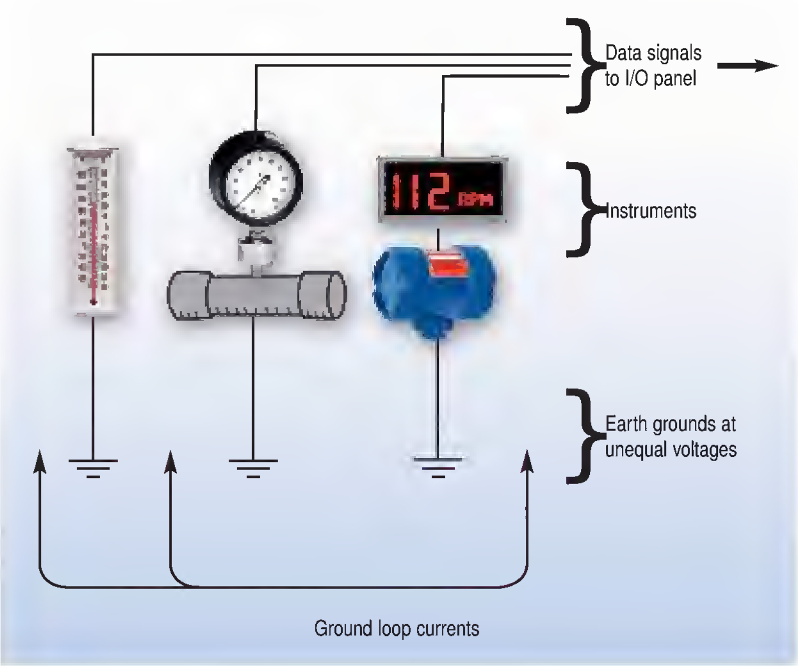
While it's generally a good practice to insulate a sensor from the thermodynamic effects of its surroundings, it's absolutely critical to establish electrical isolation. The most common electrical problems due to poor installation are *ground loops*.

Ground loops occur when an extraneous current flows through the instrumentation wiring between two points that are supposed to be at the same voltage, but aren't (see Figure 3). The resulting electrical interference can cause random fluctuations in the sensors' output and may even damage the sensors themselves.

As the name implies, ground loops most often occur when instruments and their cables are grounded improperly or not at all. Interestingly, the best way to isolate a plant's instruments from ground loop currents is to connect them together at one master grounding point.

If that's not possible, a grid of grounding points must be spread throughout the plant, making sure that all points on the grid are at the same electrical potential. Insecure connections and inadequate wires can cause a voltage imbalance in the grid and ground loops between the instruments connected to it.

**FIGURE 3. POOR GROUNDING**




*Instruments must be grounded to provide a reference voltage for the data signals they generate. Relying on earth ground is risky since not all of the earth shares the same electrical potential. The resulting currents will interfere with the sensors' signals.*

## >>Mistake #3:
### Generating gibberish

**Noise**

Ground loops are not the only source of noise that can distort a sensor's readings. *Radio frequency interference* (RFI) is even more common in plants that use walkie-talkies, pagers, and wireless networks extensively. RFI also results whenever a current changes, such as when an electromechanical contact or a static discharge generates a spark.

The sources of RFI noise must be eliminated or at least kept away from the plant's instrumentation if at all possible. Replacing electromechanical equipment with solid-state devices will eliminate arc-generated RFI. Or, it may be sufficient to simply relocate switch boxes and relays to instrument-free areas of the plant. If all else fails, it may be possible to passively shield the source of the interference or the instruments being subjected to it.

Ignoring the problem is not an option, especially when the source of the noise is ordinary house current. At 60 Hz, house current oscillates slowly enough to have an appreciable effect on some processes.

Consider the steel rolling application again. A 60 Hz noise superimposed on the output of the thickness gauge will pass through the controller and induce a 60 Hz oscillation in the roller pressure. If the sheet exits the rollers with a velocity of six feet per second, those oscillations will appear as bumps in the sheet appearing every tenth of an inch. Whether those flaws are appreciable or not will depend on the amplitude of the original noise signal, the inertia of the rollers, and the tuning of the controller.

PID controllers tuned to provide appreciable derivative action are particularly susceptible to the effects of measurement noise. They tend to react aggressively to every blip in the measurement signal to quickly suppress deviations from the setpoint. If a blip turns out to be nothing but noise, the controller will take unwarranted corrective actions and make matters worse.

**Filtering**

Unfortunately, it is not always possible to eliminate noise sources altogether. It is often necessary to filter the raw sensor data by averaging several samples together or by ignoring any changes less than some small percentage. Many digital instruments, like ABB's FSM 4000 flowmeter, come equipped with built-in filters.

However, it is a mistake to think that number crunching alone can fix all measurement noise problems. Filtering tends to increase the time required to detect a change in the measured value and can even introduce spurious information into the signal. Worse still, it can mask the actual behavior of the process if it is overdone.

It is generally more cost-effective in the long run to install sensors correctly and minimize the sources of interference than to rely strictly on mathematics to separate the data from the noise. When constructing a control loop, data filters should be applied in the final stages of the project, just before loop tuning.

## Mistake #4:
### Quitting too soon

Even when the data filters are in place and the last loop has been tuned, the project isn't over. There are some commonly neglected chores that should continue as long as the instrumentation system is in place.

**Calibration**

Most instrumentation engineers know that a sensor must be calibrated in order to associate a numerical value with the electrical signal coming out of the transmitter. Yet all too often, the instruments are calibrated just once during installation then left to operate unattended for years.

The result is an insidious problem known as *drift*. A sensor's output tends to creep higher and higher (or lower and lower), even if the measured variable hasn't changed. Deposition on the sensing surfaces, corrosion in the wiring, and long term wear on moving parts can all cause an instrument to begin generating artificially high (or low) readings. As a result, the controller will gradually increase or decrease its control efforts to compensate for a non-existent error.

Analog instruments are particularly susceptible to drift, much like old FM radios. The slightest nudge on the dial could cause the radio to lose its signal. With modern digital radios, the one true frequency for each station is digitally encoded at

a fixed value. Similarly, modern instruments that employ digital signal processing can't be "nudged." They maintain the same calibration in the field as in the lab.

Drift can also be reduced by the choice of sensing technology. Temperature sensors with mineral insolated cables, for example, are less prone to drift. Drift due to wear can be eliminated entirely by choosing instruments with no moving parts, like ABB's swirl and vortex meters.

And even when drift cannot be eliminated, recalibrating every sensor in the plant at intervals recommended by their manufacturers can accommodate it. Unfortunately, project engineers are often so anxious to finish a job and get on with operating the process that they neglect such basic maintenance.

Arguably the most challenging sources of drift are those that vary over time. Deteriorating probes and moving parts beginning to wear out can slowly change an instrument's accuracy. So maintenance calibration is required periodically even if there are no known issues with the instrument.

Some manufacturers are recognizing the time and efforts involved in traditional recalibration exercises and are designing instrumentation products to simplify matters. For example, the CalMaster portable calibrator from ABB provides in-situ calibration verification and certification of ABB's MagMaster electromagnetic flowmeters without requiring access to the flowmeter or opening the pipe.

Instead, the operator simply connects a CalMaster to the flowmeter's transmitter and a PC. A Windows interface guides the operator through a series of tests to evaluate the status of the transmitter, sensor, and interconnecting cables. The tests are complex, but so automated that the whole calibration routine can be accomplished in 20 minutes.

Once the tests are complete, CalMaster will evaluate the measurements taken. If all satisfy the calibration requirements, then a calibration certificate can be printed either at that time or later. These certificates can then be catalogued in order to meet auditing and regulatory requirements such as ISO 9001.

An added benefit of CalMaster is that it can be used as a diagnostic and condition monitoring tool. It automatically stores all measured values and calibration information in its own database files for each meter, thus maintaining a calibration history log and making it easier to undertake long-term trend analysis. Detailed observation can give early warning of possible system failure, enabling the maintenance engineer to anticipate problems and take proactive remedial action.

Such automated systems make routine verification of flowmeter calibration and the traceability of information much less cumbersome and costly than in the past. In the water industry, for example, such tasks formerly entailed mechanical excavation of the flowmeter resulting in a disruption of the water supply and a substantial investment in manpower and equipment.

### Planning for the road ahead

All too often, an expansion project begins with weeks of wondering why the existing instrumentation system was constructed the way it was and why it doesn't match the project's original plans. To avoid this, future planning should be a part of your implementation process and also include thorough documentation of what's been done before. Someone will eventually want to expand the project and will need to know exactly which instruments have been placed where, what the instruments were supposed to be accomplishing, and how they were installed and configured.

Even if the instrumentation system is never expanded, it will eventually have to be repaired. Wires break and sensors wear out. A good inventory of the system components will indicate what needs to be replaced, but that's only half the battle. Replacement parts must be acquired along with the technical specs necessary to install them correctly.

An ongoing replacement parts program is a must. Either the original vendor must make provisions for stocking replacements (or upgrades) for all the instruments they've provided to date, or the project engineers must continue to monitor their suppliers to make sure that spare parts remain available. For hard-to-find instruments, it may even be necessary to maintain an in-house supply of replacement parts, just in case.